METHOD AND SYSTEM FOR CORRELATING AND COMBINING PRODUCTION AND NON-PRODUCTION DATA FOR ANALYSIS

TECHNICAL FIELD

The present invention generally relates to integrated circuit manufacturing. The present invention also generally relates to methods for reducing integrated circuit manufacturing abnormalities. The present invention also generally relates to a method to correlate production data and non-production data from an integrated circuit manufacturing process for data analysis.

BACKGROUND

The current rapid progress of design rules and processing technology in semiconductor manufacturing makes yield and characteristics analysis more and more difficult and complicated. Typically production data is stored in one database, and non-production data is stored in another database. Data analysis is performed on the production data, using a variety of points for comparison. This data analysis may show abnormalities in production trends. Non-production data is separately gathered and subjected to separate analysis of conditions and identification of significant trends.

This data analysis is important to the quality of the manufactured material. Variations in production conditions can cause entire lots of product to be discarded, wasting valuable production time and money. Quick data analysis may avoid wholesale scrapping of product. Unfortunately the large magnitude of data that is collected hinders a quick analysis that would be meaningful to production goals.

Further compounding the analysis problem is that factors typically thought to be non-production are not considered in the analysis. Environmental measurements which can greatly affect the quality of manufacturing end-product are just one example of these factors. Even when one is able to qualitatively measure these factors, connecting that meaningfully to other measurements considered to be non-production for the purposes of data analysis requires a user to manually examine the data for commonalities and correlate the data based on those. Further

combining that combination with actual production data greatly compounds the amount of data as well as compounding the inability to perform meaningful and timely data analysis.

What is needed is a technique to quickly combine data from production and non-production sources into a combined set of data for quicker analysis.

SUMMARY OF THE INVENTION

An embodiment of the present invention is a method for performing data analysis on data gathered in an electronic device manufacturing process. The method includes collecting production data, collecting non-production data, keying the production data, keying the non-production data, combining the production data and the non-production data into a single data set, and analyzing single data-set. An embodiment of the present invention further includes performing calculations on the production data and the non-production data. Collection of production data includes at least one of collecting parametric production data, collecting film thickness data, critical dimension data, and any other data that is relevant to the production process and its condition. Collection of non-production data includes at least one of collecting non-production data from a single data source at a single source location or from a plurality of locations, and collecting non-production data from a single data source with some temporal periodicity. In an embodiment, the temporal periodicity is fixed. In an embodiment, the temporal periodicity is not fixed.

In an embodiment the combined single data-set is analyzed to determine trends in manufacturing parameters and enable a user to make decisions as to the continuation or non-continuation of the manufacturing process. In an embodiment, a system non-manually analyzes the data and makes a determination as to the continuation or non-continuation of the manufacturing process.

In an embodiment of the present invention, the method is performed by a computer system. In an embodiment, the computer system collects the non-production data and the production data, performs calculations on the data, keys the production data with some value, keys the non-production data with some value, combines the production data and the non-production data, analyzes the single data-

set and examines the analysis for current conditions in the manufacturing process. In an embodiment, the computer system responds to the current conditions of the manufacturing process by displaying an alert message when conditions are out of specification, or non-manually halting the production process when conditions are out of specifications.

Generally, non-production data, also called facility data, is stored with the date and time, e.g. time-stamp, as well as the location of the sampling. Production data, also known as production lot data, is stored with the date and time when the lot is processed at each step. By defining the proper relationships between location and time across the facility data and the production lot data, a system can automatically connect that data.

Generally facility data is sampled periodically with a specific frequency. One can correlate the lots that have been processed during that time period by examining the time-stamp of the lot as it underwent the current process step. The facility data can then be correlated to specific lots by weighted mean calculations.

A specific type of facility data is equipment control data, or equipment data. Such equipment data is gathered when the equipment is periodically qualified and/or during daily or other periodic checks. This is generally stored with the date and time and the equipment ID, as well as possibly, some other facility data. This equipment data can be combined with the production data by correlating the lots that have been processed during the time period between equipment qualification or other periodic checks by examining the time-stamp of the lot as it underwent an operation by the current equipment. In the case of an equipment check that resets the equipment condition, the data on the equipment can not be used, and a weighted mean calculation must be used.

A specific type of production data is pilot wafer data for a vertical furnace operation. Pilot wafers are used with actual production wafers in order to monitor the film thickness, resistivity, etc. at the process using the vertical furnace. Typically, the pilot wafer is placed at the top and bottom end of boat and a space between production lots. In order to gather this data as production data an average value of the pilot wafers is used. The pilot wafer may also be used between more

then one lot of production wafers. The average of the prior pilot wafer and the pilot wafer subsequent to the current lot must be averaged to be used as production data. The pilot wafer may also be during the processing of a particular lot. In such a case, one may use the pilot wafer directly as production data for that particular lot.

COMMONLY ASSIGNED PATENTS ON MANUFACTURING PROCESS DATA MEASUREMENT

The following patents are commonly assigned to the assignee of the current application and are exemplary of the types of measuring devices and data that could be used in an integrated circuit manufacturing facility and could be combined by an embodiment of the present invention to provide for quicker data analysis and manufacturing decisions. The documents listed herein are incorporated by reference for any purpose.

US Pat.6,256,593, "System for Evaluating and Reporting Semiconductor Test Processes;"

US Pat. 6,427,092. "Method for Continuous Non Lot-Based Integrated Circuit Manufacturing;"

US Pat. 6,446,017, "Method and System for Tracking Manufacturing Data for Integrated Circuit Parts;"

US Pat. 6,534,785, "Reduced Terminal Testing System;"

US Pat.6,594,013, "Reflectance Method for Evaluating the Surface Characteristics of Opaque Materials;"

US Pat. 6,605,159, "Device and Method for Collecting and Measuring Chemical Samples on Pad Surface Chip;"

US Pat.6,622,102, "Method and System for Tracking Manufacturing Data for Integrated Circuit Parts;" and

US Pat. 6,628,410, "Endpoint Detector and Method for Measuring a Change in Wafer Thickness in Chemical-Mechanical Polishing of Semiconductor Wafers and Other Microelectronic Substrates;"

BRIEF DESCRIPTION OF THE FIGS.

FIG. 1 is a pictorial representation of an exemplary manufacturing facility with a manufacturing process contained therein.

FIG. 2 is a flowchart illustrating generally, among other things, a method for collecting and correlating production and non-production data for analysis according to an embodiment of the present invention.

FIG. 3 is a pictorial representation of a scenario of an embodiment of the present invention.

FIG. 4 is a pictorial representation of a scenario of an embodiment of the present invention.

FIG. 5 is a flowchart illustrating generally, among other things, a method for collecting and correlating production and non-production data for analysis according to an embodiment of the present invention.

FIG. 6A is a pictorial representation of a vertical furnace operation according to an embodiment of the present invention.

FIG. 6B is a pictorial representation of a vertical furnace operation according to an embodiment of the present invention.

FIG. 7 is a block diagram illustrating generally, among other things, one example of portions of a data analysis system, and an environment with which it is used, for processing and analyzing production and non-production data.

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of exemplary embodiments of the invention, reference is made to the accompanying drawings (where like numbers represent like elements), which form a part hereof, and in which is shown by way of illustration specific exemplary embodiments in which the invention may be practices. Those embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and logical, mechanical, electrical and other changes may be made without departing from the scope of the present invention.

In the description, numerous specific details are set forth to provide a thorough understanding of the invention. However, it is understood that the invention may be practiced without those specific details. In other instances, well-known circuits, structures and techniques have not been shown in detail in order not to obscure the invention.

Parts of the description may be presented in terms of operations performed through the execution of programming instructions. As well understood by those skilled in the art, those operations may take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through, for example, electrical components.

The term "horizontal" as used in this application is defined as a plane parallel to the conventional plane or surface of a wafer or substrate, regardless of the orientation of the wafer or substrate. The term "vertical" refers to a direction perpendicular to the horizontal as defined above. Prepositions, such as "on", "side" (as in "sidewall"), "higher", "above", "lower", "over", "below", and "under" are defined with respect to the conventional plane or surface being on the top surface of the wafer or substrate, regardless of the orientation of the wafer or substrate. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims, along with the full scope of equivalents to which such claims are entitled.

FIG. **1** depicts a pictorial representation of a simplified manufacturing process for items. Items, in an embodiment, include integrated circuits. The item undergoing processing **101** enters the process **110** and exits as a finished product **102**. The process **110** is located in a larger manufacturing facility **120**. Conditions in the machine performing the process are very important to the quality of the end product **102**. The conditions of the item undergoing processing **103** are also very important to the quality of the end product. In addition, the conditions of the manufacturing facility 120 may also impact the quality of the end product. Measurements may be taken on the item **101, 102**, and **103**, as well as conditions of the actual manufacturing process **110**. These measurements can be called production data. The production data is from sources that are directly related to the

manufacturing process being performed. These sources include, but are not limited to, test probe data, parametric data, film thickness data, and critical dimension data. In an embodiment, a particular production data sample is gathered once per lot, i.e. production lot data. A production lot can be defined as a subset of the entirety of manufactured items, for example a plurality of work pieces such as electronic devices, integrated circuits, substrates, semiconductor wafers, or other similar structures in this art. A lot may further be considered as that quantity of product produced under similar conditions, at a similar establishment, over some period of time. In an embodiment, a particular production data sample is gathered multiple times per lot. In an embodiment, a particular data sample is applied across multiple production lots. Though this detailed description uses the term production data to refer to these data measurements, this is not to be taken in a limiting sense, as any data that relates directly to the manufacturing process being performed is considered to be production data, regardless of what it is actually called. Further, production data may be further defined as being either online or offline. Online data may be data which is measured directly on the item being manufactured and may be things such as the temperature of the manufactured item, or its thickness. Online data may also be data measured from the manufacturing process in question while the item is being processed. Offline data is that data that, though directly related to the manufacturing process, is not measured on the actual manufactured item or during the actual manufacturing step, such as the operating temperature of the machine, the operating pressure, or some other measurement.

The pictorial element labeled **120** represents the entire facility in which the manufacturing process resides. Measurements may be conducted on the entire facility, as well. These measurements can be called non-production data or alternatively, facility data. The non-production data is from sources not directly related to the manufacturing process. These sources include, but are not limited to, atmospheric conditions, water conditions, gas conditions, chemical conditions, exhaust pressure, and electrical conditions. In an embodiment, a particular sample is gathered from one location by one sensor. In an embodiment, a particular sample is gathered from multiple locations by multiple sensors. Alternatively, these

measurements may be called facility data as they generally, but without limitation, relate to the facility in which the production takes place. Though this detailed description uses the term non-production data, or facility data, to refer to these data measurements, this is not to be taken in a limiting sense, as any data that does not relate directly to the manufacturing process can be considered to be non-production data, or facility data, regardless of what it is actually called. This data is inputted into a data processor **130** for further analysis.

FIG. **2** presents a method, according to an embodiment of the present invention, for combining the data taken during the manufacturing process for the purposes of data analysis. Data is collected from both production and non-production sources, at **201**, **202**, **203**. Non-production sources may include, but not be limited to, thermometers providing temperature readings **201a**, barometers providing pressure measurements **201c**, staff productivity recording systems, electrical measurements **201b**, equipment control data, metrology tool calibration data, etc. Non-production sources also include sources that provide any other data relevant to the production environment, where the production environment may include, but not be limited to, the facility where the production is performed, a larger physical gathering of multiple production facilities in a single geographical location, etc. Production sources may further be divided into online production sources and offline production sources. Online production sources may include, but not be limited to, critical dimension readings **202a**, chemical sampling **202b**, surface readings, **202c**, etc. Offline production sources may include, but not be limited to, offline circuit testing **203a**, photomask inspection **203b**, operating temperature readings **203c**, etc. At **204** and **205** the non-production data and the production data are keyed to some value, respectively. In an embodiment, the data is keyed to a temporal, or date-time, value. In an embodiment, at **204**, that data is keyed with a date-time value. In an embodiment, at **205**, that data is keyed with production lot data, which may be further keyed with date-time values associated with the time that a particular production lot began a manufacturing process as well as the time that the particular production lot completed the manufacturing process. In an embodiment, non-production data is measured at a single location, such as depicted

in FIG. **3**. In an embodiment, the sampling location for the data measurement **310** is separated some distance **320** from the process equipment **301**. In an embodiment, production data is measured at a plurality of locations, such as depicted in FIG. **4**. The process equipment **301** is separated by a variable distance from the locations where data is being measured. For sampling location 1 at **310**, the distance **320** can be defined as d_1. For sampling location 2 at **410**, the distance **420** can be defined as d_2. There may be many locations where the data is being measured. For all sampling locations I at **411**, the distance **421** can be defined as d_i. Such multiple sampling locations **310**, **410**, **411** allow statistical operations on a similar type of sampled data from a plurality of different sample locations. For example, the different sample locations allow a similar type of data to be collected at a plurality of locations in a lot.

FIG. **2** further represents an embodiment of the present invention where the data being measured, both production (including online and offline) and non-production, are being measured at single locations and then being keyed at **204** and **205**. For some types of data being sampled, this may be sufficient as in the case of a single measuring device measuring a single data point that can be used without manipulation. This might include, but not be limited to, a thermometer measuring the air temperature of the entire manufacturing facility, a barometer measuring the air pressure of the entire manufacturing facility, a thickness measuring device measuring the thickness of an exemplary wafer sample, staff productivity measurements such as the number of personnel on shift, etc.

FIG. **5** is substantially similar to FIG. **2** and presents at a high level a method for combining production (including online and offline) and non-production, with the addition of steps at **206** and **207** for performing calculations on the offline data from both production and non-production sources. Considering the problem of faster data analysis, it is advantageous to calculate a single data point for a single data source. If a single data point is not found, then all data points for that data source would need to be added to the analysis of the data at **220**. This would represent a computational cost, both in resources in time that may hinder quicker, more useful data analysis.

In an embodiment, at **206** and **207**, the calculation being performed is one of weighting the data. This weighting calculation may be weighted on any number of criteria, including but not being limited to, time, distance, production lots, operators, etc. In the case of a physical distance weighting, the equation can be given as:

$$V = \sum_{n=1}^{i} \left[\frac{d_i}{\sum_{n=1}^{i} d_i} \right] S_i$$

Where, V is the calculated data point, d_i is the distance between the sampling point and the process location and S_i is the data being measured at the sampling point. This process of weighting by location may be performed on both production and non-production data, as some production data measurements may be separated by some non-fixed distance from the lot undergoing processing as some manufacturing processes are large in size.

In the case of measurements being taken over time, measurements of data points that are closer in time are more relevant to our analysis. Such data points need to weighted based on this time value. Table A represents a progression of production lots being processed, where data samples are being taken. In an embodiment, the samples are being taken at a single location at that time. In an embodiment, the samples are being taken at a plurality of locations at that substantially similar time. In such a case, a weighted mean calculation being weighted by location should be performed first. In Table A the first sampling is Sample 1 and as production lots undergo processing, subsequent measurements are taken, such as Sample 2, Sample 3, Sample 4, etc. In an embodiment, the sampling takes place at a fixed frequency such that a non-variable number of production lots are processed between measurements. In an embodiment, the sampling takes place at a non-fixed frequency such that a variable number of production lots are processed between measurements, as depicted in Table A. The calculated data point is calculated by first determining the time difference between the sample taken some time after the lot was processed and the most recent measurement taken prior to the lot beginning processing. Then weighting the sample point at each sample time by the time difference between when the actual production lot was processed and the

sample point, as shown by the exemplary equations in Table A in the Calculated Sample. A generalized equation for weighting by time over a variable time period with a variable number of lots undergoing processing between measurements can be expressed as:

$$V = \left(\frac{1}{tS_{x-1} - tS_x} \right) \left[S_x \left(tS_{x+1} - tL_v \right) + S_{x+1} \left(tL_v - tS_x \right) \right]$$

where V is the calculated lot data to be keyed to the production lot data, tS_x is the time of the most recent facility data sampling, tS_{X+1} is the time of the next consecutive facility data sampling, and tL_v is the time of processing the production lot. This weighting by time can be applied to both production data and non-production data.

Process	Time of Event	Sampled Value	Calculated Sampled Value assigned to Production Lot
Sample 1	tS1	S1	
Lot 1	tL1		$L1 = 1/(tS2 - tS1)\{S1(tS2 - tL1) + S2(tL1 - tS1)\}$
Lot 2	tL2		
Lot-$_i$	tL_i		$L1 = 1/(tS2 - tS1)\{S1(tS2 - tL_i) + S2(tL_i - tS1)\}$
Lot-$_{i+1}$	tL_{i+1}		
Lot-$_{i+2}$	tL_{i+2}		
Sample 2	tS2	S2	
Lot – $_j$	tL_j	L_j	$L_j = 1/(tS3 - tS2)\{S2(tS3 - tL_j) + S3(tL_j - tS2\ )\}$
Lot – $_{j+1}$			
Lot – $_{j+2}$			
Lot – $_{j+3}$			
Lot – $_{j+4}$			
Lot – $_{j+5}$			
Lot – $_{j+6}$			
Sample 3	tS3	S3	
Lot - $_k$	tL_k	L_k	$L_k = 1/(tS4 - tS3)\{S3(tS4 - tL_k) + S3(tL_k - tS3\ )\}$
Lot - $_{k+1}$			
Lot - $_{k+2}$			
Lot - $_{k+3}$			
Lot - $_{k+4}$			
Lot - $_{k+5}$			
Sample 4	tS4	S4	
⋮	⋮	⋮	⋮

TABLE A

In table A, $tS_{i,j,k,...}$ is defined as the time when a data sample is taken. In table A, $tL_{i,j,k,...}$ is defined as the time when a production lot process is begun. In table A, $S_{i,j,k,...}$ is defined as the data sampled. In table A, $L_{i,j,k,...}$ is defined as the lot data calculated. In the present invention the calculation performed to arrive at $L_{i,j,k,...}$ is a weighted mean calculation.

Integration of equipment data as another type of facility data presents an additional problem not addressed by the above equations. In an embodiment, this equipment data is tool qualification data. Data in respect to equipment control is sampled during periodic tool qualification. In an embodiment, the period of tool qualification is daily. This information is stored with an associated time-stamp and the equipment ID's as well as facility data. In an embodiment, this facility data is as described herein. In an embodiment, the equipment data is gathered with production data in the same way that facility data is gathered with production data. In some cases, equipment data can not be used due to maintenance that may reset the equipment condition. In an embodiment, a weighted mean calculation is used to calculate the equipment data value to be assigned to a particular lot. In an embodiment, the weighted mean calculation is weighted by time. In an embodiment, the weighted mean calculation is weighted by some value other then time.

FIG. **6A** and FIG. **6B** depict vertical furnace operations. Vertical furnace operations are part of process 110 in an embodiment. In a vertical furnace operation a pilot wafer **601** is used to monitor film thickness. It would be useful if this pilot wafer data could be gathered and stored with production data. Pilot wafers **601** may be used between single lots of production wafers **610**, between multiple lots of production wafers **610**. If a pilot wafer **601** is inserted into the space between lots, as depicted in FIG. **6A**, the calculation of the lot data can be given by the following calculation:

$$V_i = \frac{(P_i + P_{i+1})}{2}$$

where, V_i is the calculated pilot wafer data, P_i is the measured pilot wafer data and P_{i+1} is the next measured pilot wafer data. If a pilot wafer **601** is placed at the top, center and bottom of all processed lots, as depicted in FIG. **6B**, the lot data can be given by the following equations:

$$V_1 = \frac{P_1 + P_2}{2}$$

$$V_2 = \frac{P_1 + P_2}{2}$$

$$V_3 = P_2$$

$$V_4 = \frac{P_2 + P_3}{2}$$

$$V_5 = \frac{P_2 + P_3}{2}$$

where, $V_i \sim V_5$ are the calculated pilot wafer data and $P_i \sim P_3$ are the measured pilot wafer data. Pilot wafers **601** may also be used at some other interval to determine film thickness. In an embodiment, an average of pilot wafer readings before and after processing of a single lot is completed is used. In an embodiment, the first pilot wafer reading made some time after the completion of the processing of the production wafer lots is averaged with the first pilot wafer reading made some time before the processing of the production wafer lot is begun. In an embodiment, the pilot wafer reading made during the processing of lot is used as the pilot wafer data for that production wafer lot.

In an embodiment of the present invention the data collected from the various production and non-production sources is correlated, with reference to FIGS. 2 and 5. At **210** this correlation is performed non-manually using at least one point of data commonality. The points of data commonality may be amongst any number of items, including, but not limited to, production lot ID's, date-time values, locational, etc. In an embodiment, it is advantageous to provide a date-time value to all the data being calculated as it provides an easy reference from which to non-manually related the production and non-production data. Data related to the actual production lot is keyed with the time that a particular lot passed through a particular process. The production and non-production data that is gathered during the times where that lot is being processed by a particular process are weighted by location and then by time to determine a data point that is most related to the specific production lot and the specific production process that lot was going through that period.

By collecting data points that are easily related to each other by non-manual means, a system can quickly relate the data, and then analyze that data, providing the manufacturing operator with indicators as to the wellness of the manufacturing

operation. Such a system is described in further detail below and in FIG. **7**. In an embodiment, a system is used to monitor each individual manufacturing process. In an embodiment, a system is used to monitor multiple manufacturing processes. In an embodiment, the manufacturing operator monitors the readings of the system and determines whether an out of specification condition exists and can manually stop the manufacturing operation for further investigation. In an embodiment, the manufacturing operator responds to system generated messages of out of specification conditions to manually stop the manufacturing operation for further investigation. In an embodiment, the system determines, without any operator intervention, whether an out of specification condition exists and non-manually ceases the particular manufacturing process under consideration, without any operator intervention. In an embodiment, a manufacturing operator responds to conditions that are within specifications by allowing the manufacturing process to continue. In an embodiment, a system responds to conditions that are within specifications by non-manually allowing the manufacturing process to continue, without any operator intervention.

FIG. **7** depicts a block diagram of a system for implementing an embodiment of the invention analogous to the data processor **130** shown in FIG. **1**. Illustrated are a server **701** connected to a computer **702** via a network **710**. Although one server **701**, one computer **702**, and one network **710** are shown, in other embodiments any number or combination of them may be present. Although the server **701** and the network **710** are shown, in another embodiment they may not be present.

The computer **702** may include a processor **730**, a storage device **740**, a communications interface device **711**, an input device **750**, and an output device **760**, all connected via a bus **770**.

The processor **730** may represent a central processing unit of any type of architecture, such as a CISC (Complex Instruction Set Computing), RISC (Reduced Instruction Set Computing), VLIW (Very Long Instruction Word), or a hybrid architecture, although any appropriate processor may be used. The processor **730** may execute instructions and may include that portion of the computer **702** that

controls the operation of the entire computer. Although not depicted in FIG. 7, the processor **730** typically includes a control unit that organizes data and program storage in memory and transfers data and other information between the various parts of the computer **702**. The processor **730** may receive data from the input device **750**, may read and store code and data in the storage device **740**, may send data to the output device **760**, and may send and receive code and/or data to/from the network **710**.

Although the computer **702** is shown to contain only a single processor **730** and a single bus **770**, the present invention applies equally to computers that may have multiple processors and to computers that may have multiple buses with some or all performing different functions in different ways. Although the computer **702** is shown to contain only a single communications interface device **711**, the present invention applies equally to computers that may have multiple communications interface devices with some or all performing difference functions in different ways.

The storage device **740** represents one or more mechanisms for storing data. For example, the storage device **740** may include read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices, and/or other machine-readable media. In other embodiments, any appropriate type of storage device may be used. Although only one storage device **740** is shown, multiple storage devices and multiple types of storage devices may be present. Further, although the computer **702** is drawn to contain the storage device **740**, it may be distributed across other computers, for example on server **701**.

The storage device **740** includes a controller **745**, which in an embodiment may include instructions capable of being executed on the processor **730** to carry out the functions of the present invention. In another embodiment, some or all of the functions of the present invention may be carried out via hardware in lieu of a processor-based system. Although the controller **745** is shown to be contained within the storage device **740** in the computer **702**, some or all of the controller **745** may be distributed across other systems, for example on the server **701** and accessed via the network **710**.

The input device **750** may be a keyboard, pointing device, mouse, trackball, touchpad, touchscreen, keypad, microphone, voice recognition device, or any other appropriate mechanism for the user to input data to the computer **702**. Although only one input device **750** is shown, in another embodiment any number and type of input devices may be present.

The output device **760** is that part of the computer **702** that communicates output to the user. The output device **760** may be a cathode-ray tube (CRT) based video display well known in the art of computer hardware. But, in other embodiments the output device **760** may be replaced with a liquid crystal display (LCD) based or gas, plasma-based, flat-panel display. In another embodiment, the output device **760** may be a speaker. In still other embodiments, any appropriate output device suitable for presenting data may be used. Although only one output device **760** is shown, in other embodiments, any number of output devices of different types or of the same type may be present.

The communications interface device **711** is that part of the computer which communicates with the network **710**. The communications interface device **711** may be a network interface card (NIC) or modem. The NIC may include a readily available 10/100 Ethernet compatible card or a higher speed network card such as a gigabit Ethernet or fiber optic enabled card. Other examples include wireless network cards that operate at one or more transmission speeds, or multiple NICs to increase the speed at which data can be exchanged over a network **710**.

The bus **770** may represent one or more busses, e.g., PCI, ISA (Industry Standard Architecture), X-Bus, EISA (Extended Industry Standard Architecture), or any other appropriate bus and/or bridge (also called a bus controller).

The computer **702** may be implemented using any suitable hardware and/or software, such as a personal computer or other electronic computing device. Portable computers, laptop or notebook computers, PDAs (Personal Digital Assistants), two-way alphanumeric pagers, keypads, portable telephones, appliances with a computing unit, pocket computers, and mainframe computers are examples of other possible configurations of the computer **702**. The hardware and software depicted in Figure **7** may vary for specific applications and may include more or

fewer elements than those depicted. For example, other peripheral devices such as audio adapters, or chip programming devices, such as EPROM (Erasable Programmable Read-Only Memory) programming devices may be used in addition to or in place of the hardware already depicted.

The network **710** may be any suitable network and may support any appropriate protocol suitable for communication between the server **701** and the computer **702**. In an embodiment, the network **710** may support wireless communications. In another embodiment, the network **710** may support hard-wired communications, such as a telephone line or cable. In another embodiment, the network **710** may support the Ethernet IEEE (Institute of Electrical and Electronics Engineers) 802.3x specification. In another embodiment, the network **710** may be the Internet and may support IP (Internet Protocol). In another embodiment, the network **710** may be a local area network (LAN) or a wide area network (WAN). In another embodiment, the network **710** may be a hotspot service provider network. In another embodiment, the network **710** may be an intranet. In another embodiment, the network **710** may be a GPRS (General Packet Radio Service) network. In another embodiment, the network **710** may be any appropriate cellular data network or cell-based radio network technology. In another embodiment, the network **710** may be an IEEE 802.11x wireless network, where x is any alphanumeric character used to designate a specific standard. In still another embodiment, the network **710** may be any suitable network or combination of networks. Although one network **710** is shown, in other embodiments any number of networks (of the same or different types) may be present.

In an embodiment the non-manual relation and analysis of the data may be performed by computer code contained on the storage device **740** and further operated on by the processor **730** of the computer **702**. In an embodiment the analysis is displayed to a user via the output device **750**.

In an embodiment the non-manual relation and analysis of the data may be performed by the server **701** configured similarly to the computer **702** in that it has computer code contained in a storage device similar to the storage device **740** of the computer **702** and that computer code is operated on by a processor similar to the

processor **730** of the computer **702**.

In an embodiment the analysis is transmitted over a network **710** to a Client Interface 1 **780**. In an embodiment the Client Interface 1 is physically separated from the server **702**. In an embodiment the analysis is transmitted over a network **710** and further over a Wide Area Network **715**, such as the Internet, to a Client Interface 2 **785**. In an embodiment the analysis is conducted on Client Interface 1 and the data is transmitted over the communications network **710** for operations to be performed on Client Interface 1 **780**, configured similarly to the computer **702** of FIG. **7**. In an embodiment the analysis is conducted on Client Interface 2 **785** and the data is transmitted over the communications network **710**, and further over the Wide Area Network **785**, such as the Internet, for operations to be performed on Client Interface 2 **785**, configured similarly to the computer **702** of FIG. **7**.

In an embodiment, the examination of the analysis is conducted by a manufacturing operator via a Client Interface 1 **780** accessing the data remotely over a communications network **710** from a server **702**. In an embodiment, the examination of the analysis is conducted by a manufacturing operator via a Client Interface 2 **785** accessing the data remotely over a communications network **710**, and further over a Wide Area Network **715**, such as the Internet, from a server **702**.

As was described in detail above, aspects of an embodiment pertain to specific apparatus and method elements implementable on a computer or other electronic device. In another embodiment, the invention may be implemented as a program product for use with an electronic device. The programs defining the functions of this embodiment may be delivered to an electronic device via a variety of signal-bearing media, which include, but are not limited to:

(1) information permanently stored on a non-rewriteable storage medium, e.g., a read-only memory device attached to or within an electronic device, such as a CD-ROM readable by a CD-ROM drive;

(2) alterable information stored on a rewriteable storage medium, e.g., a hard disk drive or diskette; or

(3) information conveyed to an electronic device by a communications medium, such as through a computer or a telephone network, including wireless

communications.

Such signal-bearing media, when carrying machine-readable instructions that direct the functions of the present invention, represent embodiments of the present invention.

There are distinct advantages to this type of data correlation and subsequent analysis. It allows for a single trend chart to measure trends in the data. It also provides for an "apples to apples" relational study and makes a correlation study or statistical analysis simpler to achieve.